Unclassified

AD-A235 929

REPORT DOCUMENTATION PAGE

Form Approved OMB No 0704-0188

1b RESTRICTIVE MARKINGS	
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	3. DISTRIBUTION / AVAILABILITY OF REPORT: Approved for public release; Distribution unlimited
4. PERFORMING ORGANIZATION REPORT NUMBER(S): PL-TR-91-2092	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION: Phillips Lab, Geophysics Directorate; 6b. OFFICE SYMBOL (If applicable): PHG	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code): Hanscom AFB Massachusetts 01731-5000	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION; 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS: PROGRAM ELEMENT NO 61102F; PROJECT NO 2311; TASK NO G4; WORK UNIT ACCESSION NO 01

11. TITLE (Include Security Classification)
On the Significance of the Magnetospheric Effects in the Analysis of the Ground-Level Solar Cosmic Ray Event on 7 December 1982

12. PERSONAL AUTHOR(S)
E.O. Fluckiger*, E. Kobel*, D.F. Smart, M.A. Shea

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Reprint	FROM ____ TO ____	1991 April 30	4

16. SUPPLEMENTARY NOTATION *Physikalisches Institut, Universitat Bern,Sidlerstrasse 5, CH-3012 Bern, Switzerland - Reprinted from 21st International Cosmic Ray Conference, Conference Papers 7, 22-25, 1990

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Solar Cosmic Rays, Geomagnetic Field, Solar-Terrestrial physics, Ground-level events, Geomagnetic cutoff rigidities, Neutron monitors

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The ground-level solar cosmic ray event beginning about 2357 UT on 7 December 1982 occurred during a geomagnetically perturbed time period with Dst ≈ -80 nT. For a detailed analysis of the event we therefore determined the cutoff rigidities and directions of approach for a number of cosmic ray stations utilizing the trajectory-tracing technique in an appropriate model of the perturbed magnetospheric magnetic field. The results are compared with values calculated using the International Geomagnetic Reference Field for Epoch 1980.0, and the significance of the magnetospheric effects in the analysis of the event is discussed.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT: ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION: Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL: M.A. Shea	22b. TELEPHONE (Include Area Code): (617) 377-3977; 22c. OFFICE SYMBOL: PHG

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

PL-TR-91-2092

Reprint from 21st International Cosmic Ray Conference, Conference Papers, 7, 22-25, 1990.

ON THE SIGNIFICANCE OF THE MAGNETOSPHERIC EFFECTS IN THE ANALYSIS OF THE GROUND-LEVEL SOLAR COSMIC RAY EVENT ON 7 DECEMBER 1982

E. O. Flückiger, E. Kobel, D. F. Smart* and M. A. Shea*

Physikalisches Institut, Universität Bern, Sidlerstrasse 5, CH-3012 Bern, Switzerland
*Geophysics Laboratory, Hanscom AFB, Massachusetts, 01731 U.S.A.

Abstract

The ground-level solar cosmic ray event beginning about 2357 UT on 7 December 1982 occurred during a geomagnetically perturbed time period with Dst ≈ -80 nT. For a detailed analysis of the event we therefore determined the cutoff rigidities and directions of approach for a number of cosmic ray stations utilizing the trajectory-tracing technique in an appropriate model of the perturbed magnetospheric magnetic field. The results are compared with values calculated using the International Geomagnetic Reference Field for Epoch 1980.0, and the significance of the magnetospheric effects in the analysis of the event is discussed.

Introduction The 7/8 December 1982 ground-level event occurred during a geomagnetic storm (maximum Kp=6+). The 1B solar flare at heliographic coordinates S19, W86, beginning at 2336 UT on 7 December 1982 was well observed by ground-based and space-borne instruments. In both gamma-ray and hard X-ray emission there were multiple peaks with the maximum emission in hard X-rays occurring at 2351 UT. The particle increase at Earth began at 2357 UT on 7 December; this onset and the largest increase (62% in the one-minute data) were observed by the sea-level neutron monitor at Kerguelen Island. Solar protons with rigidities greater than 4.5 GV were present in this event as evidenced by the response of the neutron monitors at Jungfraujoch and Hermanus. The forward portion of the plasma generating the geomagnetic storm reached the Earth at 0329 UT on 7 December when there was a large jump in the magnitude and direction of the interplanetary magnetic field (IMF). Evidently, from both the IMF observations and the geomagnetic records, the Earth was immersed in turbulent plasma for the next 5 days. There were interplanetary magnetic field measurements available during this time from both the ISEE-3 and the IMP-8 spacecraft although there is a data gap in the IMP-J data from 1920 UT to 2400 UT on 7 December 1982.

Previous analysis of this event (Smart et al 1987) has shown that the relativistic solar proton flux was arriving from the direction of the interplanetary magnetic field even though the observed IMF direction was greatly distorted from its "normal" position. For the onset phase of this event when the IMP-J interplanetary magnetic field data resume at 0001 UT on 8 December 1982, the IMF vector direction changes between three general positions (Ness 1987). From 0001 until 0007 UT on 8 December the interplanetary magnetic field direction translates to a particle source around geographic coordinates 25°N, 80°E. From 0008 until 0011 UT on 8 December the IMF direction translates to a particle source around geographic coordinates 50°N, 45°E. From 0012 until 0031 UT on 8 December the interplanetary magnetic field direction translates to a particle source around geographic coordinates 40°N, 80°E. Initially, there was a coherent,

very anisotropic particle flow that rapidly (within 30 minutes) evolved into a wider pitch angle distribution in space. These pitch angle distributions are well represented by the exponential form developed by Beeck and Wibberenz (1986).

The previous work on this event (Smart et al 1987) could not satisfactorily explain the increases observed by neutron monitors in the deep polar cap such as at Alert and Thule by utilizing either the standard asymptotic cones calculated employing the IGRF (Peddie 1982) internal field model or a quiet magnetospheric model (Gall et al 1982). In this paper we demonstrate that the use of the Tsyganenko-Usmanov (1982) magnetospheric field model with parameter adjustments appropriate for this event results in decreased cutoff rigidities for middle and higher latitude stations and a significant distortion of the asymptotic cones for polar cap stations. Taking account of these perturbations results in a better understanding of the observations and how they relate to the perturbed magnetosphere and the anisotropy of the relativistic solar proton flux present during this event.

<u>Trajectory Calculations</u> In order to represent the magnetic field in the Earth's perturbed magnetosphere on 7 December 1982 at 2400 UT, the IGRF 1980.0 internal magnetic field model (Peddie 1982) was combined with the magnetospheric field model developed by Tsyganenko and Usmanov (1982). This model includes the magnetic fields of the ring current, the magnetic field from the magnetotail currents as well as the magnetopause contribution and the averaged magnetic effect of field-aligned currents. For the purpose of this paper the model was adjusted for a geomagnetic activity level of Kp > 3+. The combined internal and external field sources are time-dependent, allowing for the seasonal orientation of the Earth with respect to the sun. A paraboloid depicted by

$$x_{sm} = a\ (\ y_{sm}^2 + z_{sm}^2\ ) + b$$

with a = -0.05638 r_e^{-1} (Earth radii) and b = 10.11 r_e was used to represent the magnetopause.

A computer code calculating the total magnetic field, $\vec{B}$, as a function of the geographic coordinates was then implemented in a trajectory-tracing program. We have calculated, by the standard cosmic ray trajectory process, the trajectories of cosmic ray particles allowed at 40 specific cosmic ray stations for the 7/8 December 1982 ground-level event.

<u>Changes in Cutoff Rigidities</u> In Table 1 we list the calculated effective vertical cutoff rigidities obtained by employing a quiet internal magnetic field (described by the IGRF 1980, Peddie 1982) and those obtained by calculations in the Tsyganenko-Usmanov (1982) magnetospheric model adjusted to conform to this event. An inspection of this table shows that the cutoff rigidities for this perturbed magnetospheric model are decreased world-wide. At higher latitude locations the amplitude of the decrease in the effective vertical cutoff rigidity is typically 0.2 - 0.3 GV with respect to the quiescent internal magnetic field.

<u>Distortion of the Asymptotic Cones</u> In the Figures 1-6 we illustrate the "classical" asymptotic directions of approach calculated employing the IGRF 1980 internal magnetic field and the consequent modifications (as a function of rigidity) of these asymptotic directions by the perturbed magnetosphere during this event. For the following discussion the plots also include the contour lines for pitch angles of 20°, 40° and 60° with

respect to the directions of the interplanetary magnetic field as observed by the IMP-J spacecraft.

Table 1. Internal (IGRF) and Perturbed Effective Vertical Cut-off Rigidities during the 7/8 Dec 1982 Solar Cosmic Ray Event (GV)

Station	IGRF	7/8 Dec 82
Alert	0.00	0.00
Apatity	0.61	0.28
Deep River	1.15	0.90
Durham	1.61	1.43
Goose Bay	0.61	0.31
Inuvik	0.16	0.06
Jungfraujoch	4.63	4.49
Kerguelen	1.14	0.91
Kiel	2.33	2.22
Kiev	3.57	3.39
Leeds	2.25	2.07
Lomnicky Stit	4.00	3.86
Magadan	2.10	1.95
Mawson	0.20	0.00
Moscow	2.41	2.19
Mt. Washington	1.43	1.17
Oulu	0.78	0.50
Rome	6.31	6.20
Sanae	0.86	0.58
South Pole	0.09	0.00
Terre Adelie	0.00	0.00
Thule	0.00	0.00
Tixie Bay	0.45	0.25

<u>Explanation of the Observed Effects</u>
As previously noted the observed IMF direction during this event has a considerable deviation from the nominal average direction expected at 1 AU. During the onset of this event there was a very rapid increase at the Kerguelen Island neutron monitor. The maximum occurred within the time interval (from 0001 until 0007 UT) when the particle source direction as defined by the IMF direction was within about 11 degrees of the 4 GV asymptotic direction for Kerguelen as shown in Figure 1.

We note that for this event there was a very significant increase observed by the deep polar cap neutron monitors located at Alert, Canada and Thule, Greenland. However, having ascertained that the initial particle pulse was extremely anisotropic with a narrow pitch angle distribution about the interplanetary magnetic field direction, the fact that these stations observed a significant initial increase in the first five minutes of the event demonstrates that the magnetospheric effects during the 7/8 December 1982 ground-level solar cosmic ray event are important, resulting in a distortion of the asymptotic cones of acceptance toward the direction of the anisotropic particle flux. An inspection of Figure 2 shows this modification of the asymptotic cones (e.g. an approximately 40° shift in the Alert cone at 2 GV). In this figure we also show the relation between the Alert asymptotic cone of acceptance and the particle source position given by the IMF vector in the time interval from 0008 until 0011 UT on 8 December. The combination of these factors results in the significant particle increase observed by the Alert and Thule neutron monitors during the very anisotropic phase of this event.

In the succeeding figures we show the asymptotic cones of acceptance for Goose Bay, Inuvik and Tixie Bay (Figure 3), Jungfraujoch (Figure 4), Kiel (Figure 5), and Deep River (Figure 6), with respect to a particle source at 40°N, 80°E (i.e. the average particle source direction from 0012 until 0031 UT on 8 December). The general modification of the asymptotic directions for these stations due to the effects of the perturbed magnetosphere is readily apparent.

<u>Discussion and Conclusion</u> In attempting to model the world-wide response of the neutron monitor network to the relativistic solar particle event on 7/8 December 1982 we have found that the asymptotic directions and the cutoff rigidities computed in the Tsyganenko-Usmanov (1982) magnetospheric field model adjusted to the perturbation level of the magnetic storm during which the event occurred provide a significantly better fit to the observed cosmic ray intensity increases.

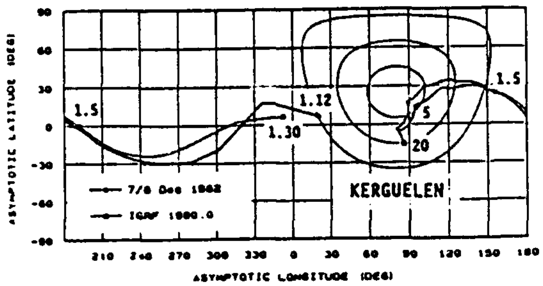

Figure 1

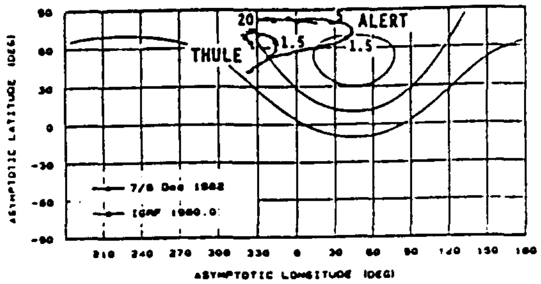

Figure 2

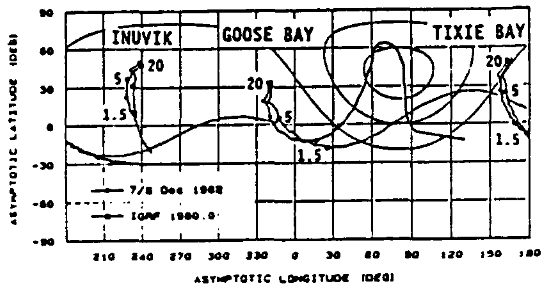

Figure 3

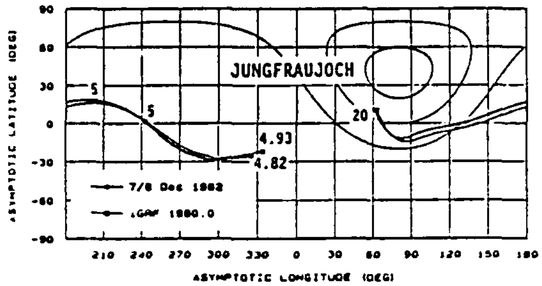

Figure 4

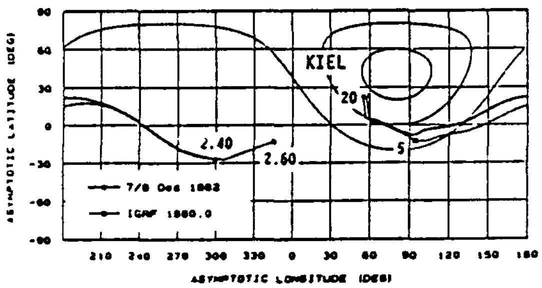

Figure 5

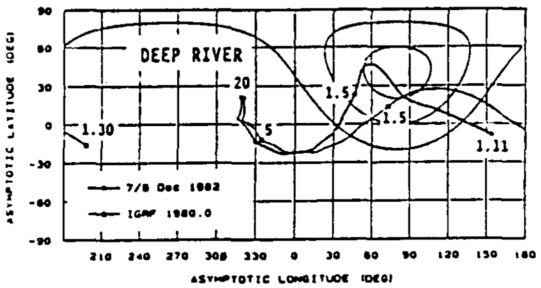

Figure 6

Figures 1-6: "Classical" asymptotic directions of approach for selected neutron monitor locations and modifications of these asymptotic directions due to the magnetospheric effects during the 7/8 Dec 1982 ground-level solar cosmic ray event. Circles and squares mark the rigidity values P = 20 GV, 5 GV and 1.5 GV (or the discontinuity cutoff P_1). Also shown are the contour lines for pitch angles of 20°, 40° and 60° with respect to the directions of the IMF as observed during the different phases of the event. For details see text.

References

Beeck J. and Wibberenz G. 1986 Ap. J. 311, 437-450

Gall R. et al 1982 "Tables of approach directions and points of entry of cosmic rays for higher latitude cosmic ray stations", Instituto de Geofisica, Universidad Nacional Autonoma de Mexico, Mexico D.F.

Ness N.F. 1987 NSSDC data set 73-078-01, NASA, Greenbelt, MD

Peddie N.W. 1982 J. Geomagn. Geoelect. 34, 309

Smart D.F. et al 1987 20th ICRC 3, 135-138

Tsyganenko N.A. and Usmanov A.V. 1982 Planet. Space Sci. 30, 985-998